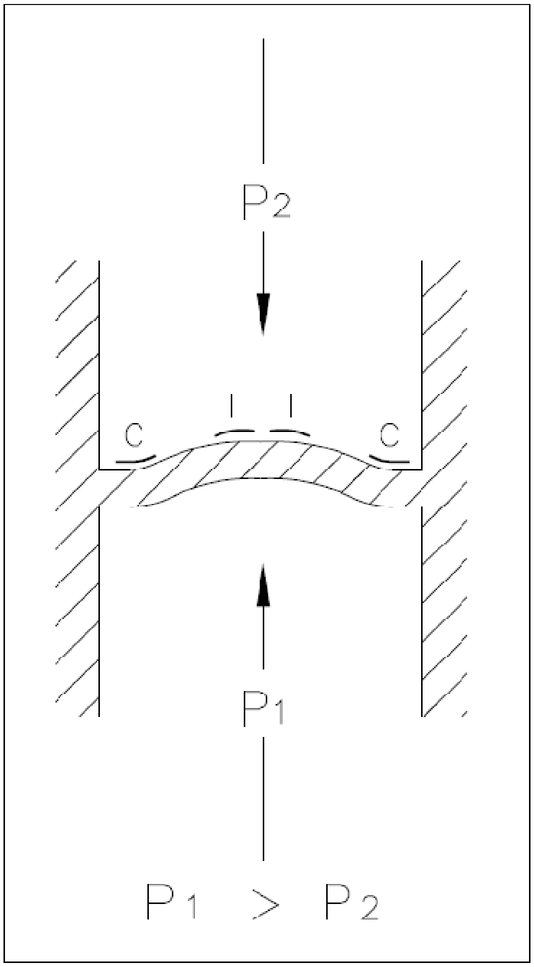
Pressure Sensing Technologies

Viatran builds pressure transmitters with four distinct pressure sensing technologies. We analyze the needs of an application and choose the technology that best serves that application. The four technologies are bonded foil strain gage, gage, silicon piezoresistive, ceramic piezoresistive, and variable capacitance. Each one is best suited for different applications and has its own advantages and limitations. We will briefly describe and explain them here.

Bonded Foil Strain Gage

Bonded foil strain gage technology is based upon Wheatstone Bridge circuitry. A balanced Wheatstone Bridge is an electrical circuit with four branches, each with a resistor of equal value. Bonded foil strain gage pressure sensing technology involves bonding four metal foil strain gages to a metal diaphragm as shown in the accompanying diagram. These strain gages correspond to the four branches of the circuit and act as the four variable resistors in the circuit. In the diaphragm's undeflected state (zero pressure applied), the Wheatstone Bridge is balanced, and no voltage output is measured.

The diaphragm reacts to applied pressure by deflecting into a bell-shaped curve. The strain gages experience strain – the outer two gages undergo compression, and the inner two undergo tension (see diagram). Their values of electrical resistance change when they are strained. When their resistance values change, the Wheatstone Bridge becomes unbalanced, and a voltage output can be measured across it.



▲ Bell shaped deflection of strain gage sensor

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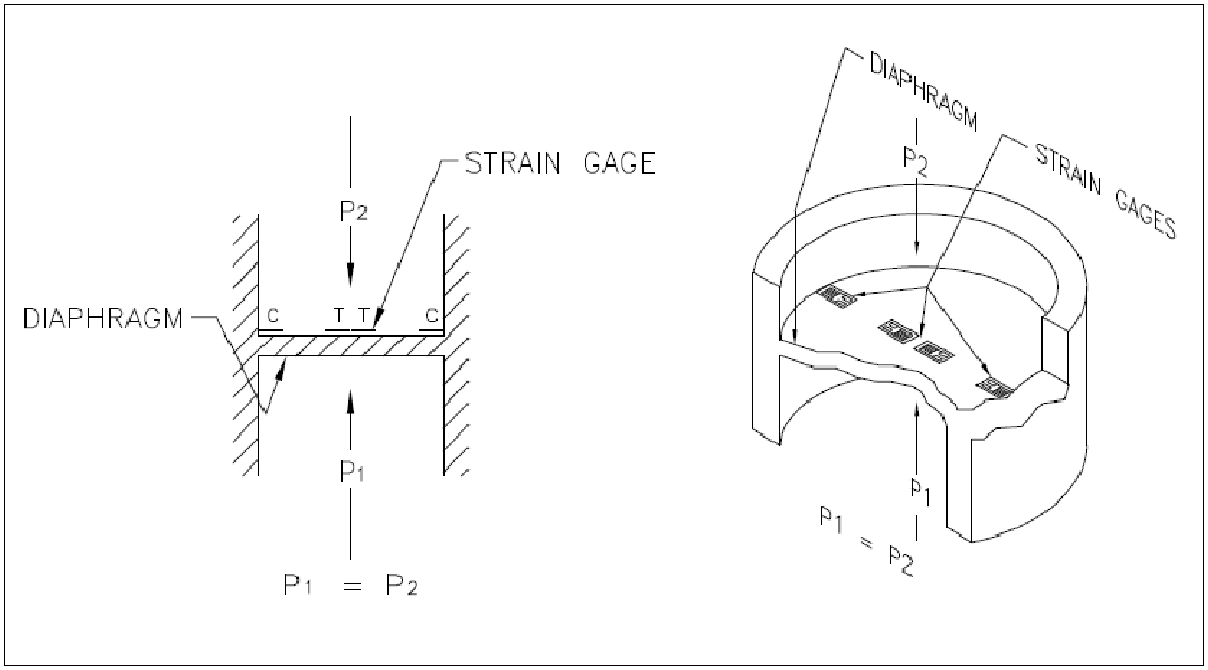
The greater the pressure applied to the diaphragm, the more it will deflect. The amount of strain on the foil strain gages and the changes in their electrical resistances are proportional to the deflection of the diaphragm. The voltage output across the Wheatstone Bridge is then also proportional to the deflection of the diaphragm. Viatran determines the pressure applied by measuring this bridge output voltage.

Bonded foil strain gage is the most reliable and durable of the four technologies. It can be used in ultra high pressure applications (0-100 through 0-100,000 psi). Its durability makes it suitable for applications which experience pressure cycling, shock, and vibrations. Another major advantage of this technology is that the foil strain gages can be matched and bonded with extreme accuracy; there is no need to include any temperature compensating devices with in the transmitter.

The main limitations of bonded foil strain gage sensing technology is its poor performance in low (<0-100 psi) pressure ranges. If the diaphragm is too thin, the strain gages begin to interfere with the diaphragm's motion.



▲ Strain gages on a machined sensor

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Silicon Piezoresistive

Silicon Piezoresistive technology is similar in theory to bonded foil strain gage-like piezoresistive on a diaphragm in a Wheatstone Bridge circuit arrangement. However, this sensing method uses silicon piezoresistive embedded in a silicon diaphragm. Silicon Piezoresistive provide a strong output signal in lower pressure ranges. They also have greater sensitivity to pressure inputs.

Though not as rugged as foil strain gage technology, silicon piezoresistive technology is better suited for lower pressure uses. It is used in the pressure ranges of 0-2 through 0-4—psi. Viatran uses this sensing technology in these low pressure applications and for liquid level measurements.

Silicon Piezoresistive Sensing technology is not suited for application which experience extreme pressure cycles, shocks, or vibrations, due to the weakness of silicon piezoresistive. It is also constrained by its rather low upper pressure limit, to applications that do not exceed 400 psi. A further restriction of this technology is that it is more difficult to match and bond silicon piezoresistive to the levels of accuracy that we can attain in bonded foil strain gag technology. For this reason, electrical compensation must be used to maintain performance specifications.

Ceramic Piezoresistive

Ceramic Piezoresistive sensing technology is also similar in theory to bonded foil strain gage technology. This sensing method uses conductive ink deposition on the reference side of a ceramic diaphragm. The conductive ink forms the variable resistance strain gages in a Wheatstone Bridge circuit. Like ceramic piezoresistive, this technology provides a srong, sensitive output signal in lower ranges.

Ceramic Piezoresistive technology is slightly more rugged than silicon piezoresistive. It is used in pressure ranages of 0-15 psi to 0-1500 psi. The ceramic wetted face isadvantageous in application where you cannot use metallic wetted parts, such as level measurement of corrosive fluids. A further advantage to this sensing technology is its cost effectiveness.

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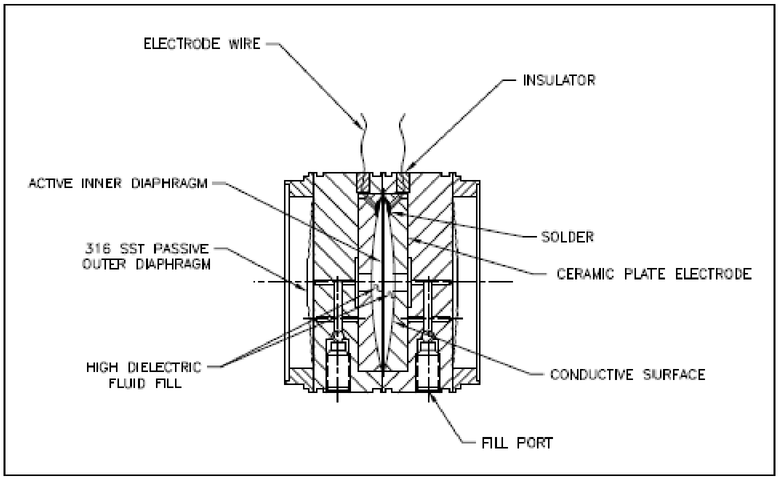
A drawback of ceramic piezoresistive sensing technology is its low upper pressure limit. The molecular structures of ceramics are such that a they do not yield before they fail completely. Whereas the elasticity of metals allow the reuse of a transmitter that has been overpressured, the brittleness of the ceramics leads to burst failures when they are overpressured. Ceramic Piezoresistive sensing technology is not suitable for use in applications which experience fast pressure cycles, shocks, or vibrations.

Another limitation of this technology is that similar to silicon strain gages, it is more difficult to match and bond ceramic strain gages, to the levels of accuracy that we can attain in bonded foil strain gage technology. So, as with silicon piezoresistive electrical compensation must be used to maintain performance specifications.

Variable Capacitance

Variable capacitance pressure sensing technology is fundamentally different from the first three. This method used changes in the capacitance of two plate capacitors to determine differences in pressure. It is ideal for applications that require "wet – wet" pressure input arrangements, i.e., where media is present on both sides of the transmitter.



Typical variable capacitance sensor (cross section) ▲

This technology provides excellent sensitivity in low pressure ranges. Viatran employs variable capacitance sensing technology in its differential pressure transmitters. However, it can also be used effectively for gage and absolute pressure measurement.

Our Variable capacitance pressure sensing technology employs three thin metallic diaphragms (see diagram). The outer two are passive diaphragms (meaning they have no spring constant), and are the wetted surfaces of the transmitter. Separating the two outer diaphragms is a silicon oil fill. Within this oil fill are two conductive inkcoated, ceramic plate electrodes and an active inner diaphragm. The inner diaphragm is called an active diaphragm because it is pulled taut in the manufacturing process and therefore possesses a spring constant. It is hydraulically coupled, through small holes in the electrodes, to the outer diaphragms.

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A charge is developed between the electrodes and the inner diaphragm. Two capacitances then exist – one between each electrode and the inner diaphragm. As long as the outer diaphragms have equal pressures on them, the inner diaphragm is not deflected and those capacitances remain equal.

Should a pressure difference exist between the two inputs of the transmitter, the wetted diaphragm on the side with the greater pressure deflects inward. This deflection pushes more oil through the holes in the electrodes and against the inner diaphragm form that side, effectively transferring the pressure on the wetted surface to the inner diaphragm. The inner diaphragm then deflects towards the opposite electrode.

Because capacitive storage is a function of the distance between each of the electrodes and the inner diaphragm, a greater capacitance forms between the inner diaphragm and the electrodes from which it is farther away. The difference in capacitances provides a measure of the pressure difference in pressure.

There are several advantages to variable capacitance pressure sensing technology. First, it is extremely sensitive to small changes in pressure; down to 1 inch of water column pressure. Also, the outer diaphragms can only deflect to the onset of the small oil-carrying holes, and there is not enough oil fill to deflect the inner diaphragm far enough to cause it to fail. In this way, our variable capacitance pressure transmitters are designed to prevent diaphragm ruptures and the need for repeat recalibrations caused by overpressures. The design is especially well suited to applications where high overpressures occur.

Variable capacitance pressure sensing technology is more complex and expensive than the other technologies. A further drawback is that signals from variable capacitance transmitters can have more noise than the other three suitable for low pressure applications.

The low level voltage output signals from all four of these sensing technologies can be amplified and/or conditioned to provide high level (0-5 volts, 0-10 volts, or 4-20 milliamps) outputs.